



Cronfa - Swansea University Open Access Repository

This is an author produced version of a paper published in:
International Journal of Sports Physiology and Performance

Cronfa URL for this paper:

<http://cronfa.swan.ac.uk/Record/cronfa51436>

Paper:

Grainger, A., Comfort, P. & Heffernan, S. (2019). No Effect of Partial-Body Cryotherapy on Restoration of Countermovement-Jump or Well-Being Performance in Elite Rugby Union Players During the Competitive Phase of the Season. *International Journal of Sports Physiology and Performance*, 1-23.

<http://dx.doi.org/10.1123/ijsp.2018-0911>

This item is brought to you by Swansea University. Any person downloading material is agreeing to abide by the terms of the repository licence. Copies of full text items may be used or reproduced in any format or medium, without prior permission for personal research or study, educational or non-commercial purposes only. The copyright for any work remains with the original author unless otherwise specified. The full-text must not be sold in any format or medium without the formal permission of the copyright holder.

Permission for multiple reproductions should be obtained from the original author.

Authors are personally responsible for adhering to copyright and publisher restrictions when uploading content to the repository.

<http://www.swansea.ac.uk/library/researchsupport/ris-support/>



Partial Body Cryotherapy does not restore CMJ or Well-Being Performance in Elite Rugby Union Players during the competitive phase of the season

Journal:	<i>International Journal of Sports Physiology and Performance</i>
Manuscript ID	IJSPP.2018-0911.R2
Manuscript Type:	Original Investigation
Date Submitted by the Author:	n/a
Complete List of Authors:	Grainger, Adam; University College Dublin, Institute of Sport and Health Comfort, Paul; University of Salford, Directorate of Sport, Exercise and Physiotherapy Heffernan, Shane; University College Dublin, Institute of Sport and Health
Keywords:	Restoration of performance, Countermovement jump, Applied rugby physiology, Real-world performance, Cold therapy, Elite athletes

SCHOLARONE™
Manuscripts

Partial Body Cryotherapy does not restore CMJ Performance or Well-Being in Elite Rugby Union Players during the competitive phase of the season

Abstract

Purpose: Partial body cryotherapy (PBC) has been shown to be beneficial for post-exercise recovery, however, no study has demonstrated the effectiveness of PBC as a recovery modality following elite rugby union (RU) training. RU is a unique sport that involves high velocity collisions with minimal protective wear and may represent a situation that could induce greater performance decrements than other sports, thus PBC could be beneficial. The application of PBC in ‘real-world’, as opposed to the laboratory setting, has rarely been investigated during the competitive phase of a playing season and warranted investigation.

Methods: In a counterbalanced sequential research design, professional rugby athletes ($n = 18$, age, 25.4 ± 4.0 years; training age, 7.2 ± 4.0 years; mass, 99.8 ± 10.6 kg and height 188.3 ± 6.0 cm) were assigned to a 12-week PBC intervention, washout period (4 weeks) and reassessed as their own controls. Total self-reported well-being, muscle soreness, sleep quality and countermovement jump (CMJ) height were assessed pre and 40 hours post ‘real world’ training (field and gym). Wilcoxon signed rank tests and Cohen’s d were used for statistical analysis. Results: No differences were observed in the PBC or control conditions ($p > 0.05$; d 0.00-0.14) for well-being ($-0.02 \pm 0.08\%$ vs. $0.01 \pm 0.06\%$), muscle soreness ($-0.01 \pm 0.11\%$ vs. $0.01 \pm 0.16\%$), sleep quality ($-0.03 \pm 0.14\%$ vs. $0.10 \pm 0.29\%$) or CMJ height (36.48 to 36.59 vs 38.13 to 37.52 cm; $p = 0.54$). Conclusions: These results suggest that the administration of PBC is ineffective at enabling the restoration of selected performance parameters during the performance maintenance phase of the competitive season. To ascertain the appropriation of its use, future investigations should seek to assess the use of cryotherapies at various phases of the elite rugby union competitive season.

Key words: Cold therapy, restoration of performance, countermovement jump, applied rugby physiology, real-world performance, elite athletes

1. Introduction

1.1

Restoration of performance in elite team sports is paramount as many athletes are required to perform optimally on a weekly basis, particularly in contact sports such as rugby union¹. As such, there is a large body of research on the restoration of performance between bouts of training activities^{2,3}. Evidence to support delayed restoration post ‘rugby match-play’ is well documented^{3,4}. McLellan et al (2001)⁴ assessed markers of post-match fatigue in elite rugby league, showing that countermovement jump (CMJ) peak power was reduced for up to 48 hours and that creatine kinase (CK) and cortisol (C) concentrations remained elevated for up to 120 hours. In rugby union, West et al.⁵ noted that peak power, assessed via CMJ, recovered no sooner than 60 hours post-match, and that neuromuscular fatigue, also assessed by CMJ, outlasted mood disturbances. Furthermore, Skein et al.⁶ showed that sleep deprivation delays the recovery of lower-body power (mean and peak CMJ distance) after a competitive rugby league match. These data show the requirement for rugby practitioners to invest in techniques that are believed to return their athletes to optimal competitive condition enabling them to train optimally in the immediate days post-match.

As a result, several recovery strategies have been developed for elite athletes to encourage restoration of performance⁷. Often these strategies come at great economic and logistic cost, particularly the various cold therapies that are regularly used in modern rugby in an attempt to enhance recovery between games. However, the effectiveness of these cold strategies remains controversial⁸. Higgins et al.⁹ reported detrimental effects of cold-water immersion (CWI: immersion of the body, except the head, into $\leq 15^{\circ}\text{C}$ water for typically 30-120s) on recovery

from rugby union specific training (phosphate decrement performance test). Whereas, Webb et al.¹⁰ reported positive effects of CWI in improving CMJ height and reducing muscle soreness following an elite rugby league match. Differences in study methodology may be the causes of these conflicting results for CWI effectiveness, with temperature (5-15°C), immersion depth (most commonly within thoracic region and total immersion of lower limbs) and duration (CWI=5-15min) all differing¹¹.

Partial body cryotherapy (PBC), which is typically utilised within 24 hours of exercise completion, is another well used cold exposure recovery strategy that consists of exposure to extremely cold air in temperature-controlled cryosaunas (that are maintained at -110°C to -140°C, for ~3 minutes). Both PBC and WBC (whole body cryotherapy) involve extreme cold air exposure (PBC individuals heads are outside of the cryosauna and cold exposure) and have been reported to demonstrate similar thermal responses¹². The effectiveness of WBC use has been criticised in rugby^{13,14}, while assessment of PBC has not yet occurred. PBC/WBC differs to CWI, in controllability (temperature and hygiene), practicality (less immediate loss of muscle function) and proposed mechanism. PBC is proposed to affect the sympathetic nervous system due to the more extreme temperatures, whereas CWI is thought to reduce systemic inflammation possible due to the hydrostatic pressure¹⁵. As identified by Murray et al.⁸, local vasoconstriction, caused by water pressure and temperature, may reduce fluid diffusion into interstitial space, thereby assisting in reducing muscle damage and acute inflammation. Furthermore, although PBC may be less thermally efficient, it is important for practitioners to note that CWI is administered at inconsistent and higher temperatures than PBC. However, the physiological rationale for CWI has been contested. For example, when comparing muscle, skin, and core temperature, Costello et al.¹⁶ noted that skin temperature was significantly lower ($p > 0.05$) immediately after WBC compared to CWI. These greater reductions are likely due

to the extreme temperatures associated with WBC, yet this view of greater reductions in tissue temperature associated with WBC is further disputed¹⁷.

To date, the majority of studies assessing WBC in athletes have employed laboratory-based training stress^{18,19}, with limited evaluation of field based ‘real world’ environments¹³. While the two settings are inextricably linked and vital to our practical understanding, laboratory-based testing is often impractical and costly. Thus performance testing (such as jump performance) and subjective well-being (WB) assessments that are accessible (and regularly utilised) to ‘real world’ elite and non-elite athlete practitioners are vital practical tools. These assessments have become popular to assess chronic physiological changes and with the aim of enabling more informed decision making³. The application of sport science research that appreciates practical ‘real world’ context over more controlled laboratory based conclusions is a recommended practice and likely to positively impact practitioner direction²⁰, particularly in relation to restoration of performance. Currently, limited research exists confirming the worth of either PBC or WBC following ‘elite’ rugby union training recovery¹³ and therefore warranted investigation. As the majority of rugby research on this topic has focused on WBC, investigating PBC is warranted particularly considering that it is of more practical tool for elite sport due to cost and portability.

Therefore, the aim of this study was to assess the effectiveness of PBC pre and post ‘real world’ field and gym based training in a group of professional rugby players in the restoration of total-WB, muscle soreness, sleep quality, and CMJ performance, compared to a control condition. Based on the existing evidence, it was hypothesised that PBC would improve restoration of self-reported WB, muscle soreness, sleep quality and CMJ height following a standard period of professional rugby union field and gym based training.

2. Material and methods

2.1 Subjects

Eighteen male professional rugby union players (age 25.4 ± 4.0 years, training age 7.2 ± 4.0 years, mass, 99.8 ± 10.6 kg and height 188.3 ± 6.0 cm) participated in this investigation (forwards $n = 10$; backs $n = 8$). All players regularly competed in the English Premiership Rugby competition during the 2015-2016 season and played >60 mins per game during each arm of trial period. Results throughout the test and control periods were evenly distributed and therefore not considered to have had an influence upon the present results. No players experienced time-loss injury or illnesses that may have impaired their performance for at least six months prior to and throughout the period of assessment. All participants provided written informed consent, and ethical approval was granted by the University Institutional Review Board. This study was conducted in accordance with the Declaration of Helsinki (2013).

2.2 Design

In a counterbalanced sequential design, randomly selected players were exposed to both the PBC and control conditions between 10am and 12pm. Players were administered PBC for 12 weeks (minimum of nine weeks of exposure per player) as this was seen as an appropriate period for PBC treatment to elicit a chronic effect, rather an acute response. During the final 3 weeks of this period, well-being (WB) and CMJ data were collected on one occasion pre training and prior to PBC, and post training following PBC at the same timepoints. All testing was conducted midweek between games at an English Premiership training facility specifically designed to facilitate performance assessment. Players were tested on one occasion each between weeks 9 and 12 due to the need for testing to be match dependant and not all players playing in every match throughout this period. Following these 12 weeks, players undertook

a 4-week 'wash out' period consisting of the same field and resistance based training. Players were then again assessed for well-being (WB) and CMJ pre training without PBC, and post training again without PBC (control condition), midweek between games. During the 'No-PBC' period, players were all tested at the same timepoint having all played in the same match. All prior and subsequent training weeks involved both field and gym based training, with repeated testing taking place at consistent time-points pre and post training. Throughout these training weeks GPS data were used to quantify field load, while gym load was standardised and consistent - with typical in-season elite rugby union prescribed microcycles²¹. No other additional recovery strategies were administered during the study period and dietary intake was consistent throughout. Changes in total-WB, sleep quality, muscle soreness and CMJ, for each individual, were assessed both with and without PBC at 40 hours post-match. No formal training was administered between testing time-points pre and post condition.

2.3 Partial body cryotherapy (PBC)

In accordance with Selfe et al.¹⁴, PBC was administered for two minutes at a temperature of -120°C in a cryosauna (*CryoPod*, Cumbria, UK). During the PBC sessions, players wore minimal clothing with shorts, socks, woollen slippers, woollen facemask, gloves and a headband worn to avoid frostbite. Throughout the PBC session participants were instructed to remain in motion for the entire 2-minute period.

2.4 Self report well being questionnaires

All players completed a questionnaire upon waking in their own homes via an online player management tool. This questionnaire assessed subjective responses to questions relating to sleep quality, muscle soreness, energy levels, mood and appetite - based on prior

recommendations²². Total-WB assessment was scored out of 50 (arbitrary units), with 10 being the highest rating a player could provide for each individual part of the questionnaire. Sleep and muscle soreness were further analysed separately due to their previously reported sensitivity in assessing restoration post rugby match-play^{23,24}.

2.5 Field-based training load

This study incorporated total distance covered as a measure of player field load, with this metric having been shown to provide excellent reliability in team sport settings²⁵. GPS units (*StatSports Viper*, Northern Ireland) were worn by all players on all training days at a sampling frequency of 10 Hz. GPS data (from field training) was collected on the day of assessment and is presented as means \pm SD.

2.6 Gym-based training load

During gym-based resistance training sessions, sets were multiplied by repetitions and were used to quantify gym-load (arbitrary unit = AU). As reported elsewhere, higher gym loads were assumed to induce greater muscular fatigue²⁶. Gym load was monitored throughout the duration of the 12-weeks to ensure no influence on either the PBC or control conditions, or the 'wash-out' periods.

2.7 Performance testing

From a standing position, with hands resting on the hips and feet extended throughout the flight to prevent tucking of the knees, two CMJs were performed by all players prior to resistance or field based training. Two jumps separated by 2 minutes were used as this is what is regularly used in 'real world' settings, with the best of performance used for further analysis. A rapid countermovement was conducted by the participants descending until the knee angle reached

approximately 90°, followed immediately by a vertical jump. Participants were instructed to jump as high as possible and to flex their knees on landing to absorb the impact. Prior to testing, players were instructed to perform a prescribed dynamic stretching and warm up jump routine, which included jogging, lower-limb mobility exercises and three sub-maximal CMJ efforts. Players were familiar with the CMJ protocol, having performed it on a regular basis over preceding months.

All jumps were performed on an *OptoJump* optical measuring system (*Microgate*, Bolzano, Italy). The *OptoJump* system, which consists of one receiver and one transmitter bar, with jump height calculated via flight time:

$$\text{Jump Height} = (9.81 \text{ m.s}^{-2} \times \text{flight time}^2)/8$$

2.8 Statistical Analysis

Statistical analysis was performed using SPSS Version 24. Normality was assessed using the Shapiro-Wilks test and Wilcoxon signed ranked tests were used to compare changes in total-WB, muscle soreness, sleep quality and CMJ between conditions (PBC and control). Paired samples T tests were used to assess training load (GPS variables). Cohen's *d* effect sizes (ES) were used to assess the magnitude of any effect and interpreted as follows; trivial = <0.2, small = 0.2 – 0.49, medium = 0.50 – 0.79 and large > 0.8. Post-hoc statistical power was calculated using G Power 3.1.

3. Results

3.1 Training load

The 12 week gym based training load for PBC (375.0 ± 17.3 AU) was no different from the control period (395.0 ± 5.8 AU; $p = 0.07$). There were no differences in GPS field-based training load, between matches (PBC 6209.6 ± 868.4 m versus control 6218.1 ± 733.8 m; $p = 0.90$, Cohen's $d = 0.01$) or training (PBC 3594.3 ± 514.8 m versus control 3623.4 ± 418.9 m; $p = 0.63$, Cohen's $d = 0.06$).

Shapiro-Wilks test for normality revealed that Total-WB, sleep, muscle soreness and CMJ were not normally distributed ($p > 0.05$). GPS values for both the match and training were normally distributed ($p < 0.05$). A total of eighteen participants were sufficient to deliver an actual power of 0.71 (effect size of 0.5).

3.2 Total-WB, muscle soreness and sleep quality pre and post intervention

No differences were identified for total-WB ($p = 0.36$), muscle soreness ($p = 0.66$) and sleep quality ($p = 0.07$) between conditions (Figure 1). Table 1 illustrates the absolute and percentage change in total-WB, muscle soreness and sleep quality between time-points during both conditions, all with trivial effects.

3.3 CMJ performance

There was no difference ($p = 0.54$) in CMJ performance between conditions (Figure 2). Table 1 illustrates the absolute and percentage change in CMJ performance between time-points during both conditions, with trivial effects (Cohen's $d = 0.15$).

4. Discussion

Contrary to our hypothesis that PBC would improve the restoration of performance following an elite rugby union training week, the present results show no change, with only trivial effect, for total-WB, sleep quality, muscle soreness, or CMJ performance. Furthermore, in the control condition, there was no decline in total-WB, sleep quality, muscle soreness or CMJ performance over time and may suggest that additional recovery modalities may not be required during this phase of an elite rugby season. These results are in agreement with recent data in trained males showing no effect of WBC on recovery following a hamstring damaging protocol¹⁸ and no effect of WBC on vertical jump following high intensity exercise²⁷.

While comparable studies utilising PBC following a rugby union training environment (assessing jump performance and self-report WB) do not exist, studies assessing the influence of CWI on muscle soreness and recovery of CMJ performance are noted^{28,29}. The administration of CWI after rugby is believed to improve perception of well-being through reduction in nerve conduction velocity associated with improved parasympathetic reactivation³⁰. This effect is hypothesised to be due to low temperatures penetrating the skin and subcutaneous tissue to the muscle. However, when comparing CWI to the colder WBC, Costello et al.³¹ reported that WBC elicits a superior decrease in skin temperature, yet more recently Mawhinney et al.¹⁷ reported the opposite effect.

Nonetheless, the present study showed no positive effects of PBC on sleep quality or total-WB in elite rugby athletes. However, recent data from non-contact sports (swimmers) have reported that daily use of WBC increased sleep quantity and exercise capacity while also reducing perceived fatigue³². It is believed that this perceived benefit in swimmers may be due to improved heart rate variability through the cold-induced vasoconstriction and

parasympathetic reactivation that occurs³³. Combining these data and our results to suggest that PBC may be applicable in a non-contact sporting environment but may not be effective in the contact sporting environment, of elite rugby union where muscle damage is greater, particularly during this phase of the rugby season.

Regarding restoration of physiological performance (CMJ in the present study), Ferreira-Junior et al.³⁴ found that one PBC session enhanced the acute recovery of eccentric strength following drop jump protocol. Whereas other research on functional performance has shown that drop jump height increases with the repeated use of WBC, but showed no influence after a single bout³⁵. To elicit this response, Westerlund et al.³⁵ exposed non-athletic participants to three separate rooms (each with a different temperature; -10, -60 and -110°C) for a three-month period. This structure of varying temperature cold therapy, is impractical in the elite applied sport settings and therefore is less comparable, but noteworthy, to the present 'real world' results. Nonetheless, in a study assessing CMJ performance, following a repeated sprint exercise in professional academy soccer players, a single bout of WBC also had no influence upon rate of restoration at 135°C³⁶ – supporting the present data in elite rugby union players. Given these data it is plausible that the potentially beneficial effects of cold therapies may be effectible as an acute response, but not in the more chronic design of the present study.

It is important to note that other studies have reported that treatment with WBC have shown positive influences on feelings of fatigue and soreness following metabolic and mechanical stress³⁷ initial muscle damage/associated inflammation^{34,38} and jump performance³⁵. However, these studies were all conducted in a well-controlled environment and may not reflect actual sporting environments. As such, it is possible that during the elite competitive rugby season when practitioners aim to maintain athletes' physiological performance/well-being, as opposed

to significantly improve it - in-week training stimulus may not be sufficient to evoke a decrement in CMJ performance and WB. Thus, during the competitive phase of the season superfluous recovery modalities such as PBC may not be required and could explain the lack of association shown in the present results and others. This may suggest a further rationale for the lack of translation from the acute response³⁴ to the present study design which reflects the 'real world' scenario in which cold therapies are currently being applied in elite sport (i.e. chronic use over many weeks). It is yet to be seen whether cold therapies could be a beneficial modality for the restoration of performance during a more condensed competitive period such as rugby 7's or international tours, but would be a worthy investigation.

Despite a near-significant difference in selected training load variables being apparent in this study, the real world insignificance of the findings are of importance. This study has attempted to address the lack of empirical research on this expensive yet relatively unknown recovery modality, while also considering the notion that differences in training load no matter how small could have influenced our results³⁹. A lack of clear guidance existing upon meaningful change in internal and external training load variables associated with rugby union and the reality of testing in applied settings should be considered within the study findings, yet the findings and applied nature to the study design should also not be considered as a limitation.

The present sample size is a minor limitation, yet the 'real world' settings resulted in limited opportunities for access to elite players. However, by virtue of the 'eliteness' of our sample and assessing these players, uniquely, during the training week we believe that the results are valid and applicable to the wider rugby community. Due to the nature of PBC administration, it is impossible to blind players from the study design and therefore potentially influencing findings. Treatment belief and the nocebo effect may have been a contributing factor in the

present results. Future investigations might consider the efficacy of PBC with a jump test that may be more sensitive to detect alterations in 'real world' neuromuscular performance (assessing strength-endurance rather than maximal muscle power)²⁸. Furthermore, focus should not only be on larger sample sizes, but more in-depth 'real world' accessible physiological responses and during competitive phases that might require additional recovery modalities such as condensed periods of high intensity play.

5. Practical applications

The present data do not support the use of PBC for the restoration of jump performance or markers of WB during the competitive phase of the season in elite rugby union, when psychophysiological performance is being maintained. The absence of a performance or WB decrement in the control condition and the **insignificance of the findings are not considered a limitation, more a consequence of applied testing alongside training load variables that are yet to have meaningful change values assigned to them in elite rugby union settings**. Nonetheless, the current data on the efficacy of PBC to improve training or game recovery remains inconsistent and therefore the use of PBC cannot be recommended during the maintenance phase of the season. Given the considerable economic and logistic cost to clubs, more research is required with large sample sizes and over large time scales to investigating the various psychophysiological intensities throughout the competitive season and identify the appropriate phases for effective use of cold therapies.

6. Conclusions

The present data do not support the use of PBC for the restoration of jump performance or markers of well-being in elite rugby union athletes during the competitive phase of the season, where physiological and WB performance is being maintained. Currently, the data on the efficacy of PBC to improve training or game recovery remains inconsistent and given the

considerable economic and logistic cost to clubs, more research is required with large sample sizes and over large time scales before the use of PBC can be recommended.

References

1. Roe G, Darrall-Jones J, Till K, et al. The effect of physical contact on changes in fatigue markers following rugby union field-based training. *European journal of sport science*. 2017;17(6):647-655.
2. Kennedy RA, Drake D. The effect of acute fatigue on countermovement jump performance in rugby union players during preseason. *The Journal of sports medicine and physical fitness*. 2017;57(10):1261-1266.
3. Tavares F, Smith TB, Driller MW. Fatigue and recovery in rugby: A review. *Sports Medicine*. 2017;47(8):1515-1530.
4. McLellan CP, Lovell DI, Gass GC. Markers of postmatch fatigue in professional rugby league players. *Journal of Strength and Conditioning Research*. 2011;25(4):1030-1039.
5. West DJ, Finn CV, Cunningham DJ, et al. Neuromuscular function, hormonal, and mood responses to a professional rugby union match. *Journal of Strength and Conditioning Research*. 2014;28(1):194-200.
6. Skein M, Duffield R, Minett GM, Snape A, Murphy A. The effect of overnight sleep deprivation after competitive rugby league matches on postmatch physiological and perceptual recovery. *International Journal of Sports Physiology and Performance*. 2013;8(5):556-564.
7. Gill ND, Beaven CM, Cook C. Effectiveness of post-match recovery strategies in rugby players. *British Journal of Sports Medicine*. 2006;40(3):260-263.
8. Murray A, Cardinale M. Cold applications for recovery in adolescent athletes: a systematic review and meta analysis. *Extreme Physiology and Medicine*. 2015;4:17-17.
9. Higgins TR, Heazlewood IT, Climstein M. A random control trial of contrast baths and ice baths for recovery during competition in u/20 rugby union. *Journal of Strength and Conditioning Research*. 2011;25(4):1046-1051.
10. Webb NP, Harris NK, Cronin JB, Walker C. The relative efficacy of three recovery modalities after professional rugby league matches. *Journal of Strength and Conditioning Research*. 2013;27(9):2449-2455.
11. Leeder J, Gissane C, van Someren K, Gregson W, Howatson G. Cold water immersion and recovery from strenuous exercise: a meta-analysis. *British Journal of Sports Medicine*. 2012;46(4):233-240.
12. Savic M, Fonda B, Sarabon N. Actual temperature during and thermal response after whole-body cryotherapy in cryo-cabin. *Journal of Thermal Biology*. 2013;38(4):186-191.
13. Galliera E, Dogliotti G, Melegati G, Romanelli M, Cabitza P, Banfi G. Bone remodelling biomarkers after whole body cryotherapy (WBC) in elite rugby players. *Injury-International Journal of the Care of the Injured*. 2013;44(8):1117-1121.
14. Selfe J, Alexander J, Costello JT, et al. The effect of three different (-135 degrees C) whole body cryotherapy exposure durations on elite rugby league players. *Plos One*. 2014;9(1).

15. Schaal K, Le Meur Y, Bieuzen F, et al. Effect of recovery mode on postexercise vagal reactivation in elite synchronized swimmers. *Applied Physiology Nutrition and Metabolism-Physiologie Appliquee Nutrition Et Metabolisme*. 2013;38(2):126-133.
16. Costello JT, Culligan K, Selfe J, Donnelly AE. Muscle, skin and core temperature after-110 degrees c cold air and 8 degrees c water treatment. *Plos One*. 2012;7(11).
17. Mawhinney C, Low DA, Jones H, Green DJ, Costello JT, Gregson W. Cold-water mediates greater reductions in limb blood flow than whole body cryotherapy. *Medicine and Science in Sports & Exercise*. 2017.
18. Fonda B, Sarabon N. Effects of whole-body cryotherapy on recovery after hamstring damaging exercise: A crossover study. *Scandinavian Journal of Medicine & Science in Sports*. 2013;23(5):E270-E278.
19. Pournot H, Bieuzen F, Louis J, Fillard J-R, Barbiche E, Hausswirth C. Time-course of changes in inflammatory response after whole-body cryotherapy multi exposures following severe exercise. *Plos One*. 2011;6(7).
20. Buchheit M. Houston, we still have a problem. *International Journal of Sports Physiology & Performance*. 2017;12(8):1111-1114.
21. Jones TW, Smith A, Macnaughton LS, French DN. Strength and conditioning and concurrent training practices in elite rugby union. 2016;- Publish Ahead of Print.
22. Tavares F, Healey P, Smith T, Driller M. The effect of training load on neuromuscular performance, muscle soreness and wellness during an in-season non-competitive week in elite rugby athletes. *The Journal of sports medicine and physical fitness*. 2017.
23. Shearer DA, Jones RM, Kilduff LP, Cook CJ. Effects of competition on the sleep patterns of elite rugby union players. *European Journal of Sport Science*. 2015;15(8):681-686.
24. Thornton HR, Delaney JA, Duthie GM, Dascombe BJ. Effects of Preseason Training on the Sleep Characteristics of Professional Rugby League Players. *International journal of sports physiology and performance*. 2018;13(2):176-182.
25. Coutts AJ, Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science and Medicine in Sport*. 2010;13(1):133-135.
26. Howatson G, Brandon R, Hunter AM. The response to and recovery from maximum-strength and-power training in elite track and field athletes. *International journal of sports physiology and performance*. 2016;11(3):356-362.
27. Vieira A, Bottaro M, Ferreira-Junior JB, et al. Does whole-body cryotherapy improve vertical jump recovery following a high-intensity exercise bout? *Open access journal of sports medicine*. 2015;6:49.
28. Garcia CA, da Mota GR, Marocolo M. Cold water immersion is acutely detrimental but increases performance post-12 h in rugby players. *International journal of sports medicine*. 2016;37(08):619-624.
29. Takeda M, Sato T, Hasegawa T, et al. The effects of cold water immersion after rugby training on muscle power and biochemical markers. *Journal of Sports Science and Medicine*. 2014;13(3):616-623.
30. Buchheit M, Peiffer JJ, Abbiss CR, Laursen PB. Effect of cold water immersion on post-exercise parasympathetic reactivation. *American Journal of Physiology-Heart and Circulatory Physiology*. 2009.

31. Costello JT, Culligan K, Selfe J, Hayes GM, McInerney CD, Donnelly AE. Comparison of the effects of cold air (-110 degrees c) and water (8 degrees c) cryotherapy on intramuscular temperature. *Medicine and Science in Sports and Exercise*. 2012;44:748-749.
32. Schaal K, Le Meur Y, Louis J, et al. Whole-body cryostimulation limits overreaching in elite synchronized swimmers. *Medicine and Science in Sports and Exercise*. 2015;47(7):1416-1425.
33. Hausswirth C, Schaal K, Le Meur Y, et al. Parasympathetic activity and blood catecholamine responses following a single partial-body cryostimulation and a whole-body cryostimulation. *Plos One*. 2013;8(8).
34. Ferreira-Junior JB, Bottaro M, Vieira A, et al. One session of partial-body cryotherapy (- 110° C) improves muscle damage recovery. *Scandinavian journal of medicine & science in sports*. 2015;25(5):e524-e530.
35. Westerlund T, Oksa J, Smolander J, Mikkelsen M. Neuromuscular adaptation after repeated exposure to whole-body cryotherapy (-110 degrees C). *Journal of Thermal Biology*. 2009;34(5):226-231.
36. Russell M, Birch J, Love T, et al. The effects of a single whole body cryotherapy exposure on physiological, performance and perceptual responses of professional academy soccer players following repeated sprint exercise. *Journal of Strength and Conditioning Research*. 2016;31(2):415-421.
37. Pointon M, Duffield R. Cold water immersion recovery after simulated collision sport exercise. *Medicine and Science in Sports and Exercise*. 2012;44(2):206-216.
38. Costello JT, Baker PRA, Minett GM, Bieuzen F, B. SI, Bleakley C. Whole-body cryotherapy (extreme cold air exposure) for preventing and treating muscle soreness after exercise in adults. *Cochrane Database of Systematic Reviews*. 2015.
39. Taylor RJ, Sanders D, Myers T, Abt G, Taylor CA, Akubat I. The dose-response relationship between training load and aerobic fitness in academy rugby union players. *International journal of sports physiology and performance*. 2018;13(2):163-169.

Table 1. Effect size statistics for total-WB, muscle soreness, sleep quality and CMJ change between (Cohen’s *d*)

Condition	Effect size within groups, pre to post (Cohen’s <i>d</i>)		Effect size between groups (Cohen’s <i>d</i>)
	PBC	Controls	
Total-WB (arbitrary units)	0.06	0.10	0.14
Muscle soreness (arbitrary units)	0.11	0.00	0.00
Sleep quality (arbitrary units)	0.14	0.26	0.87
CMJ height (cm)	0.01	0.11	0.15

No differences between any variables during both conditions ($p > 0.05$)

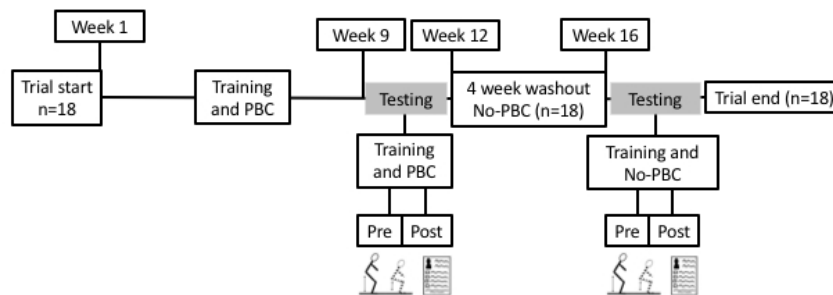


Figure 1 Schematic diagram of experimental design timeline.

Figure 1. Schematic diagram of experimental design timeline.

338x190mm (54 x 54 DPI)

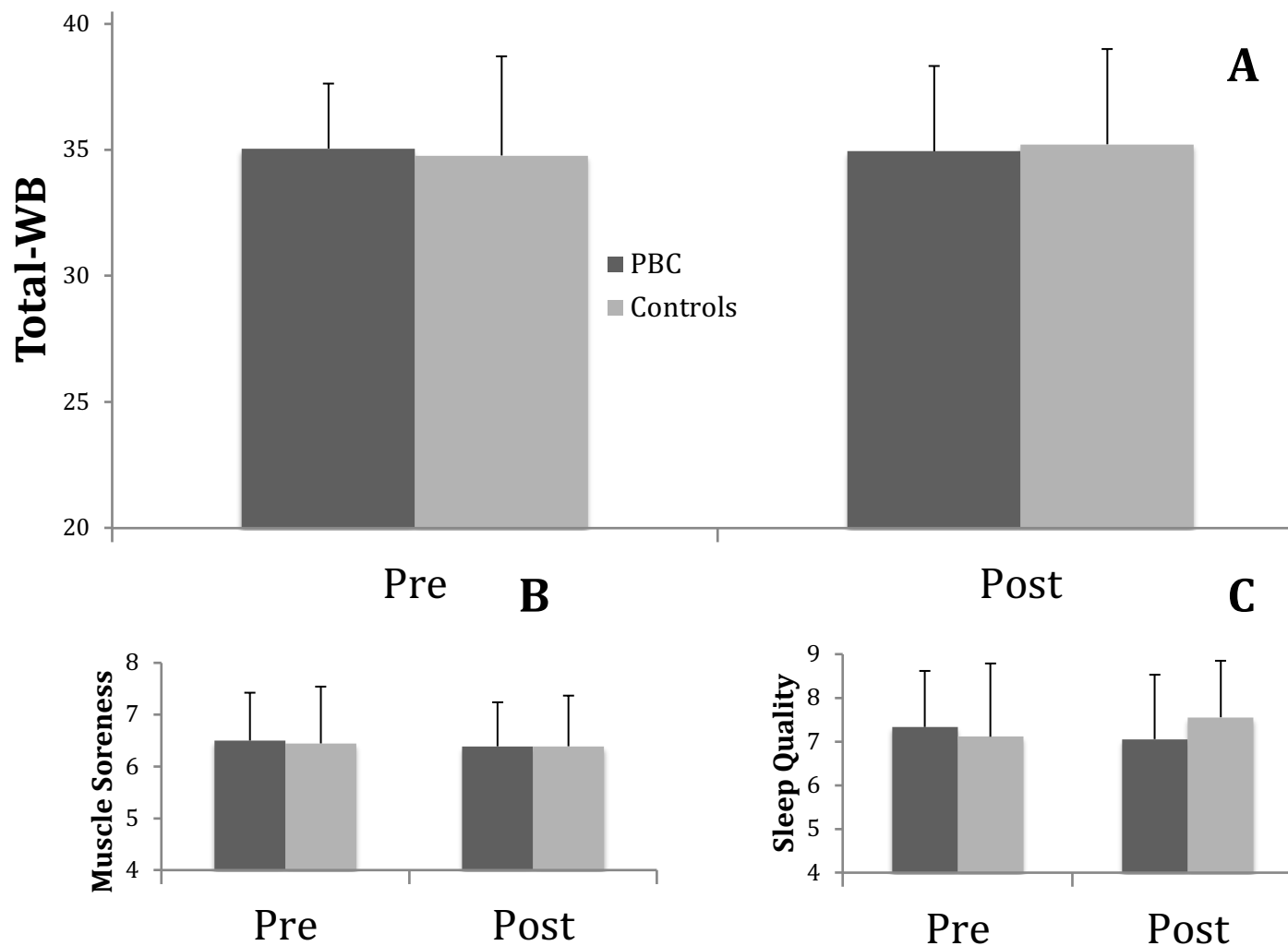


Figure 2. Total-WB (A), muscle soreness (B) and sleep quality (C) pre and post training between PBC and

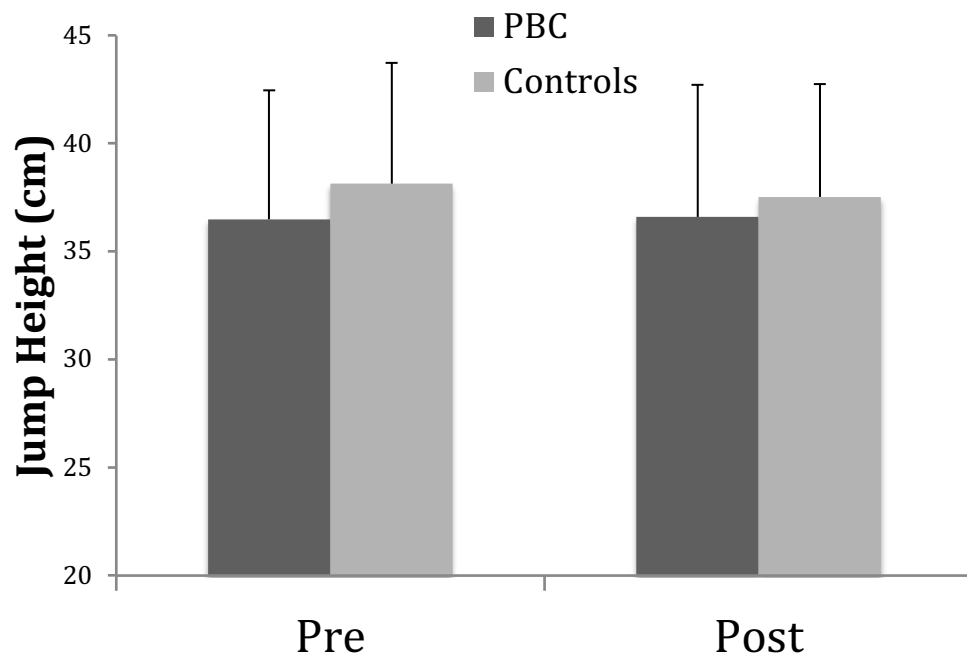


Figure 3: CMJ height pre and post training for PBC and controls